NAM V4.0 Update

20 April 2015

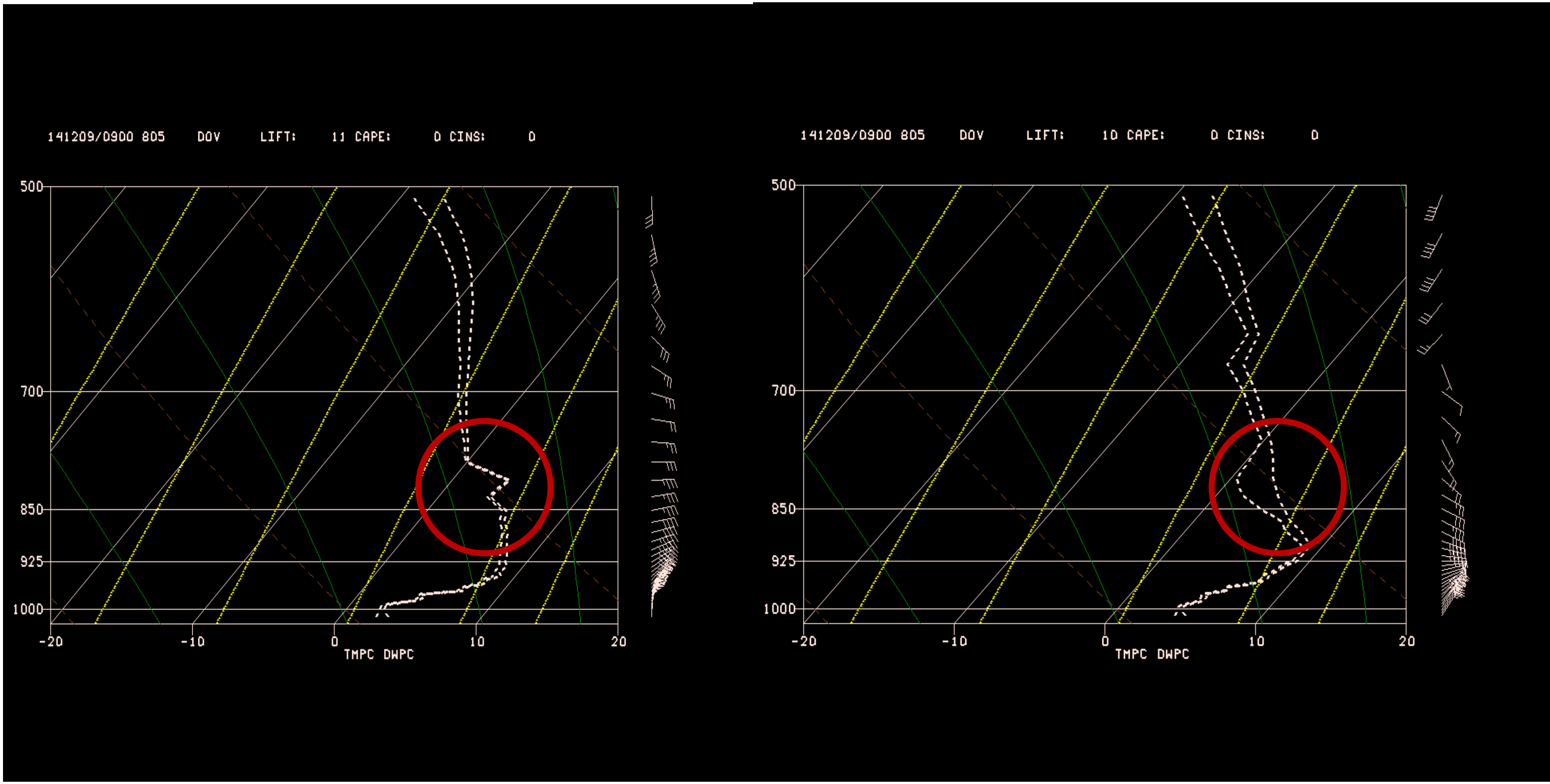
Highlights of major changes planned

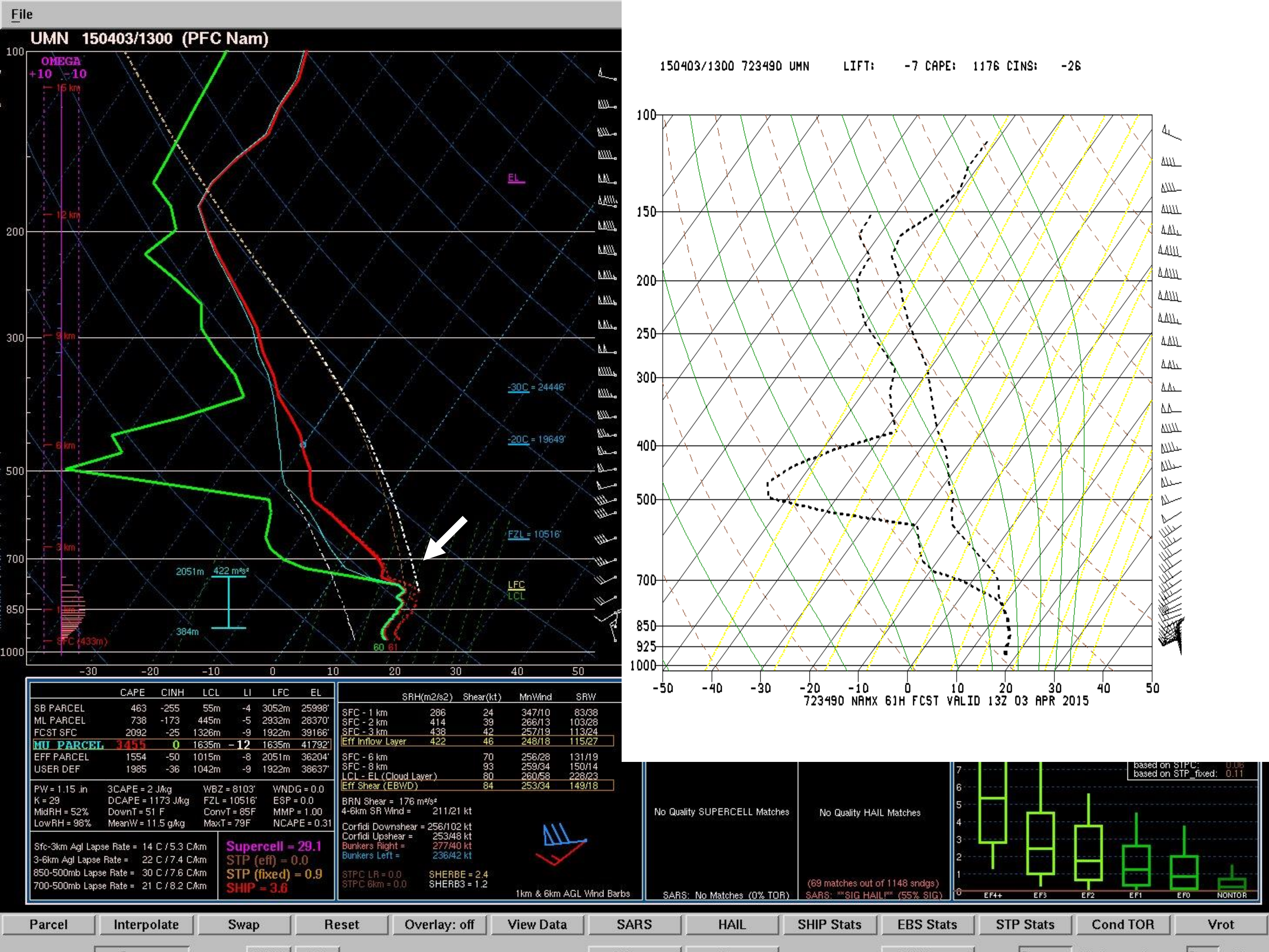
- Resolution changes
  - CONUS nest resolution : 4 km --> 3km
  - Alaska nest resolution : 6 km --> 3km
  - CONUS fire weather nest resolution : 1.333 km --> 1.5 km
- Replace 12-km NDAS (3-hourly analyses/forecasts) with hourly assimilation cycle (“NAMRR”) which will include 12 km parent domain + CONUS/Alaska nest
- Model physics changes : new shallow convection, “drier” soil adjustment, PBL changes (enhanced mixing at top of PBL in moist conditions)
- Use of radar-derived temperature tendencies in model's diabatic digital filter
- GSI changes :
  - New code allows use of full T574 EnKF members, instead of having to truncate them to T254
  - More weight given to ensemble background covarinaces over static (75-25 instead of 50-50)
  - 4-d version of hybrid analysis (tentative)
- Resume use of AFWA snow depth w/envelope adjustment (used in global)
- Tropical cyclone relocation

Physics change : new shallow convection

- Eliminates unrealistic model profiles (moist absolutely unstable layers)
- Improves cool season QPF bias in 12 km NAM (long-standing problem)
- Some cases show more precipitation in warm sector

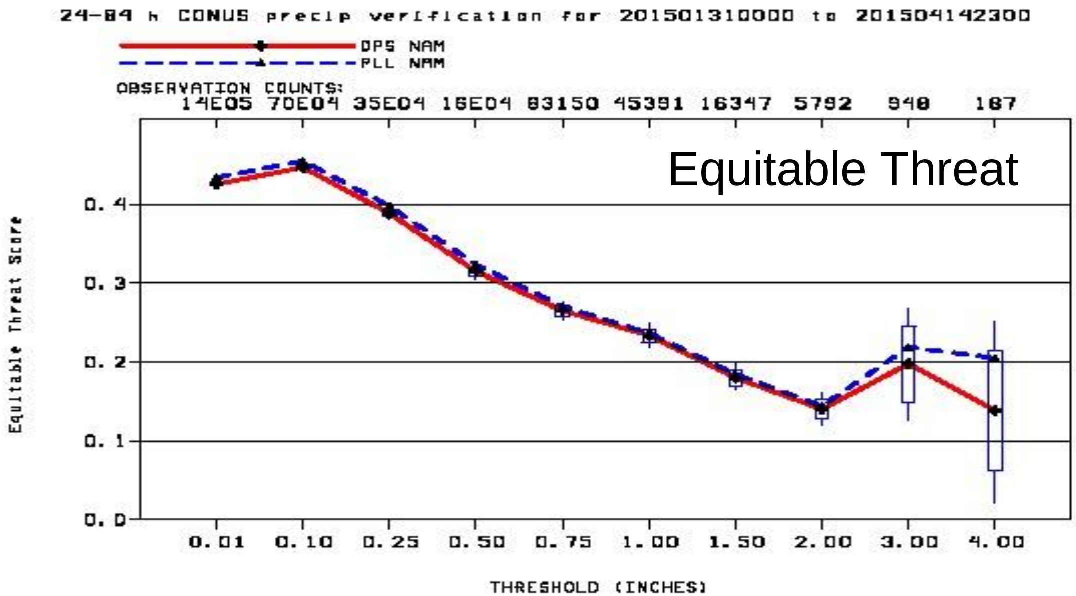
Impetus to use new shallow Cu: elimination of unrealistic “MAUL” model profile in NAM: from 12z 12/8/14 NAM; 21-h fcst at Dover, DE

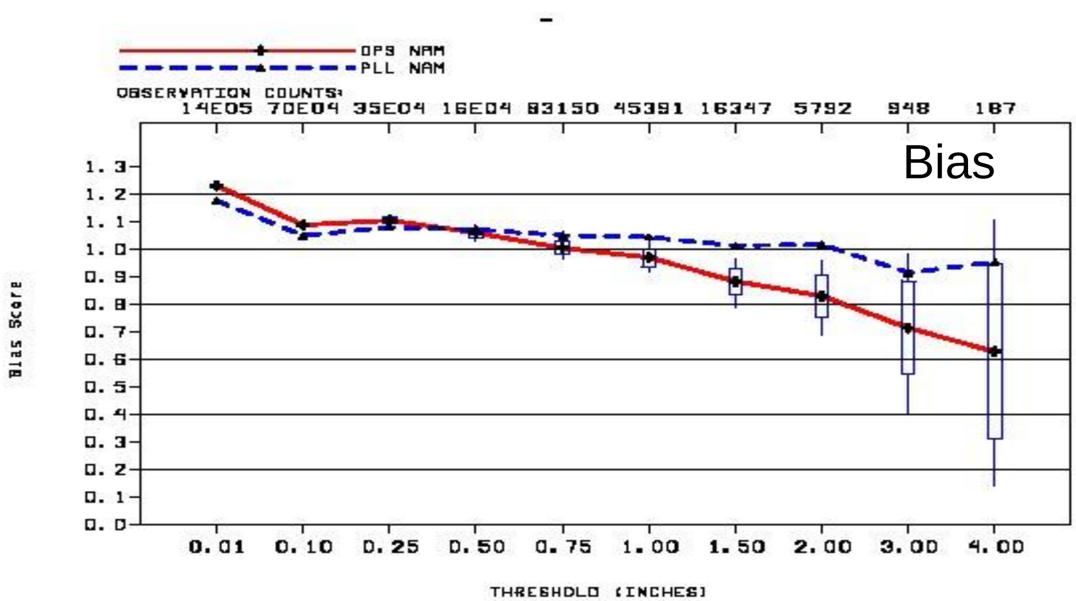




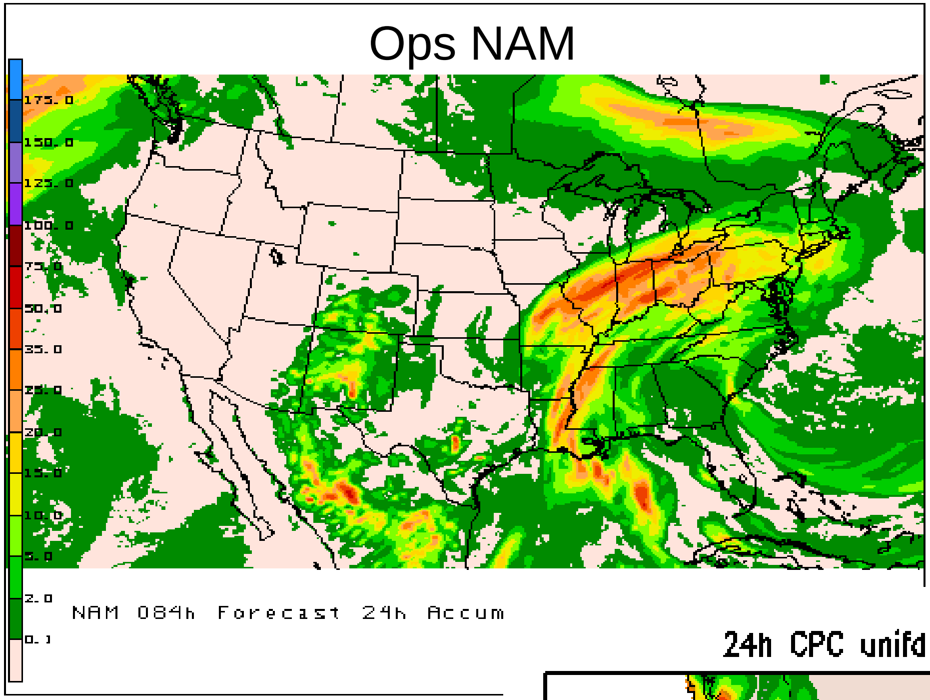
File
UMN 150403/1300 (PFC Nam)
OMEGA +10 -10
EL
-30C = 24446'
-20C = 19649'
FZL = 10516'
LFC
LCL
2051m 422 m²/s²
384m
SFC (433m)
CAPE CINH LCL LI LFC EL
SB PARCEL 463 -255 55m -4 3052m 25998'
ML PARCEL 738 -173 445m -5 2932m 28370'
FCST SFC 2092 -25 1326m -9 1922m 39166'
MU PARCEL 3455 0 1635m -12 1635m 41792'
EFF PARCEL 1554 -50 1015m -8 2051m 36204'
USER DEF 1985 -36 1042m -9 1922m 38637'
PW = 1.15 in 3CAPE = 2 J/kg WBZ = 8103' WNDG = 0.0
K = 29 DCAPE = 1173 J/kg FZL = 10516' ESP = 0.0
MidRH = 52% DownT = 51 F ConvT = 85F MMP = 1.00
LowRH = 98% MeanW = 11.5 g/kg MaxT = 79F NCAPE = 0.31
Sfc-3km Agl Lapse Rate = 14 C / 5.3 C/km
3-6km Agl Lapse Rate = 22 C / 7.4 C/km
850-500mb Lapse Rate = 30 C / 7.6 C/km
700-500mb Lapse Rate = 21 C / 8.2 C/km
Supercell = 29.1
STP (eff) = 0.0
STP (fixed) = 0.9
SHIP = 3.6
SRH(m2/s2) Shear(kt) MnWind SRW
SFC - 1 km 286 24 347/10 83/38
SFC - 2 km 414 39 266/13 103/28
SFC - 3 km 438 42 257/19 113/24
Eff Inflow Layer 422 46 248/18 115/27
SFC - 6 km 70 256/28 131/19
SFC - 8 km 93 259/34 150/14
LCL - EL (Cloud Layer) 80 260/58 228/23
Eff Shear (EBWD) 84 253/34 149/18
BRN Shear = 176 m²/s²
4-6km SR Wind = 211/21 kt
Corfidi Downshear = 256/102 kt
Corfidi Upshear = 253/48 kt
Bunkers Right = 277/40 kt
Bunkers Left = 236/42 kt
STPC LR = 0.0 SHERBE = 2.4
STPC 6km = 0.0 SHERB3 = 1.2
1km & 6km AGL Wind Barbs
No Quality SUPERCELL Matches
SARS: No Matches (0% TOR)
No Quality HAIL Matches
(69 matches out of 1148 sndgs)
SARS: **SIG HAIL!** (55% SIG)
based on STPC: 0.06
based on STP_fixed: 0.11
EF4+ EF3 EF2 EF1 EF0 NONTOR
Parcel Interpolate Swap Reset Overlay: off View Data SARS HAIL SHIP Stats EBS Stats STP Stats Cond TOR Vrot
150403/1300 723490 UMN LIFT: -7 CAPE: 1176 CINS: -26
723490 NAMX 61H FCST VALID 13Z 03 APR 2015

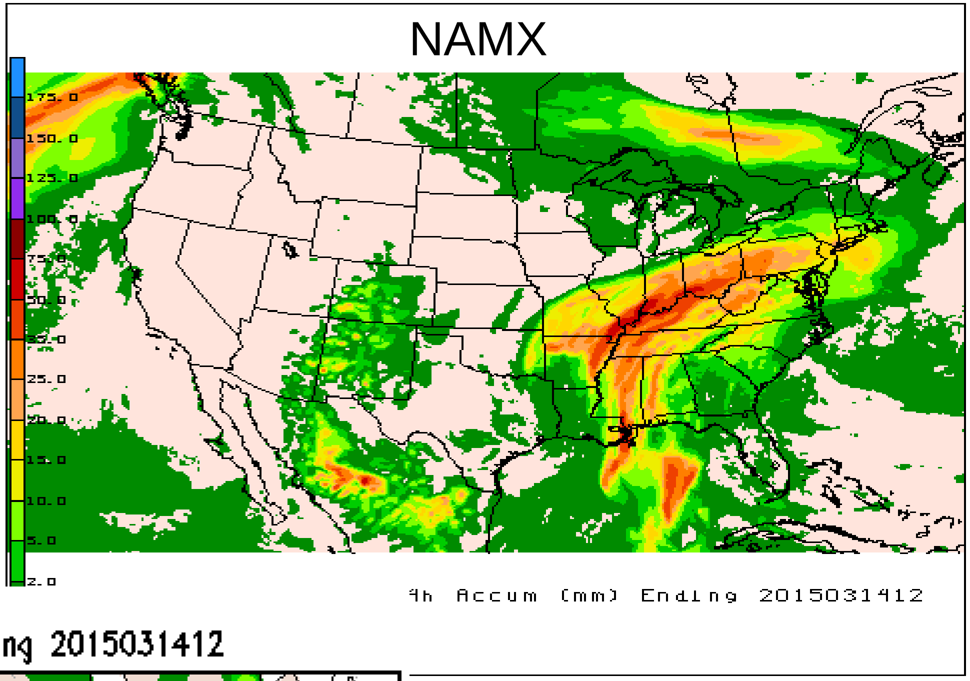
12 km parent QPF scores ; all fcsts : Ops = Red; Pll=Blue ; 31 Jan – 14 Apr

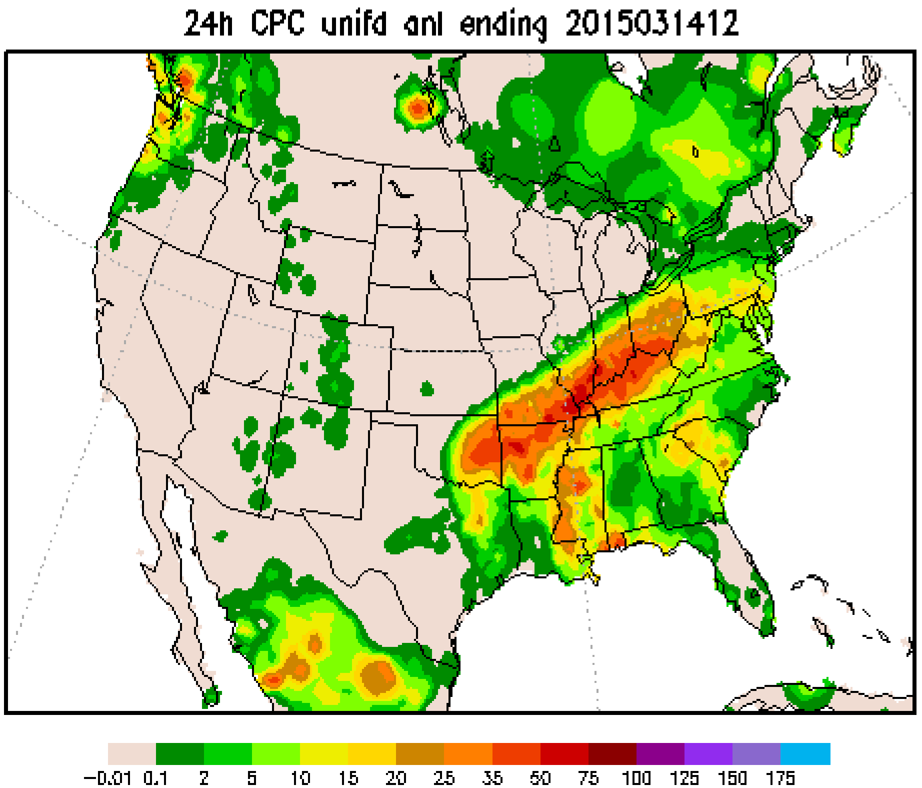




24-h precip; 84-h fcsts valid 12z 3/14

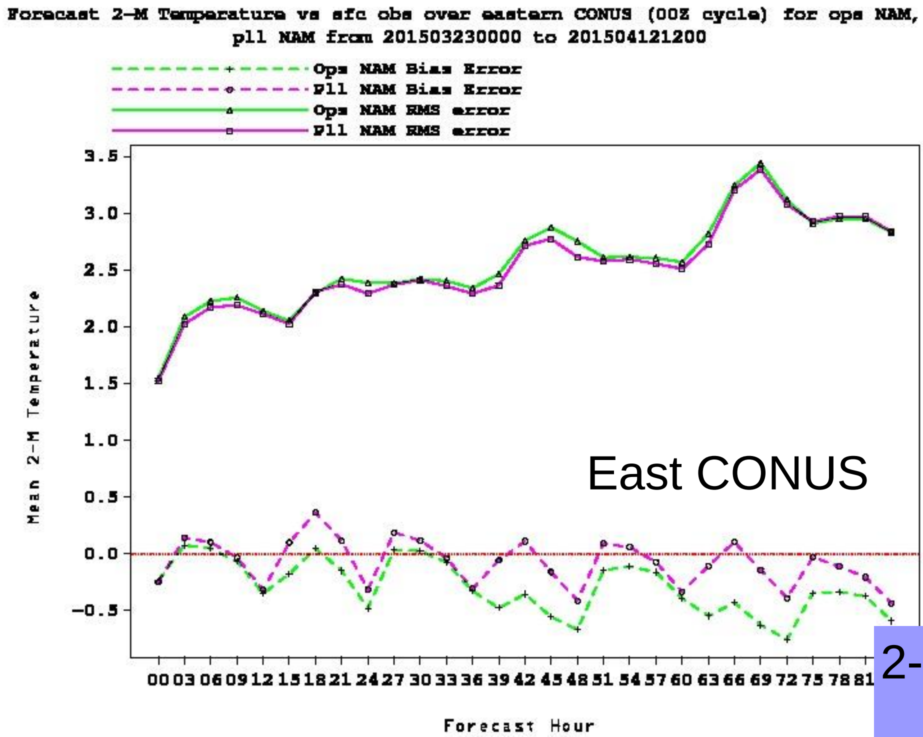


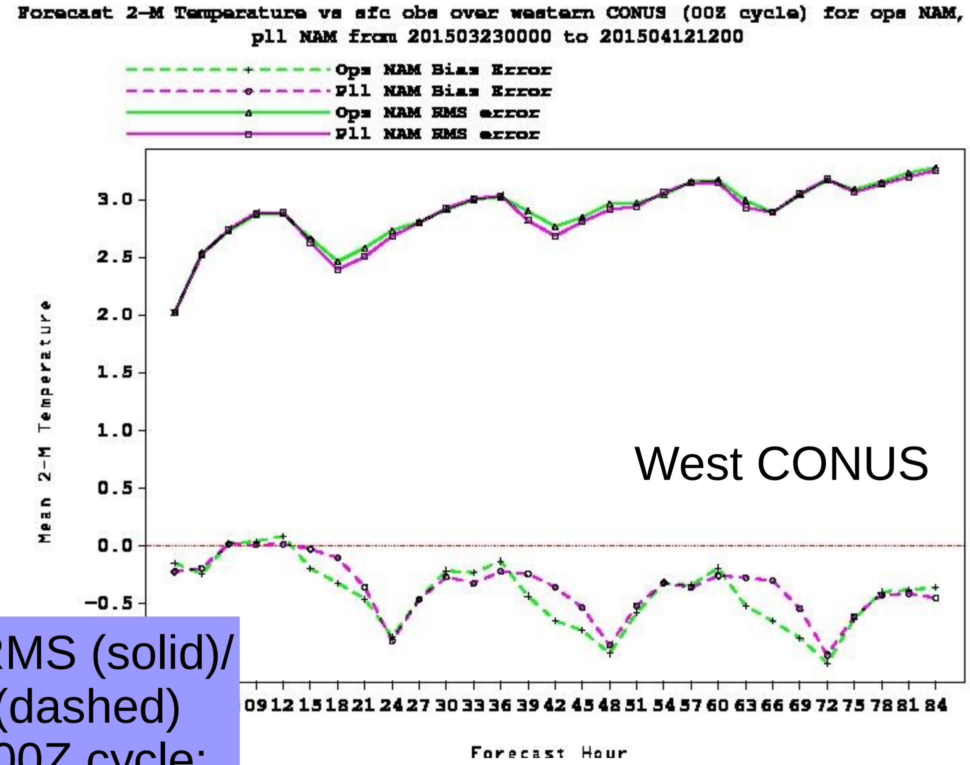




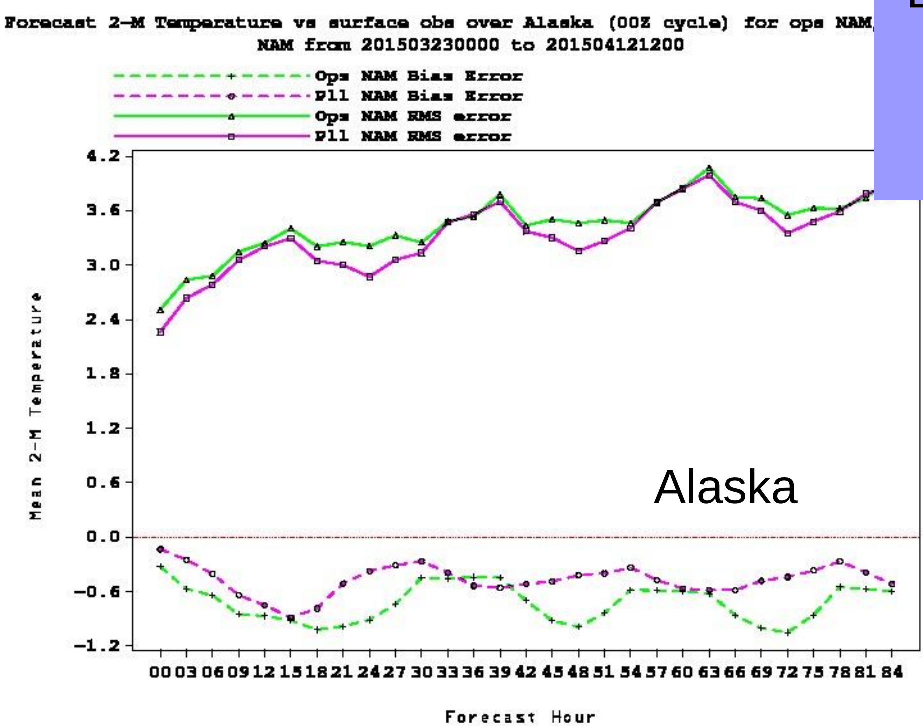
Physics Changes :“Dry” Soil Adjustment

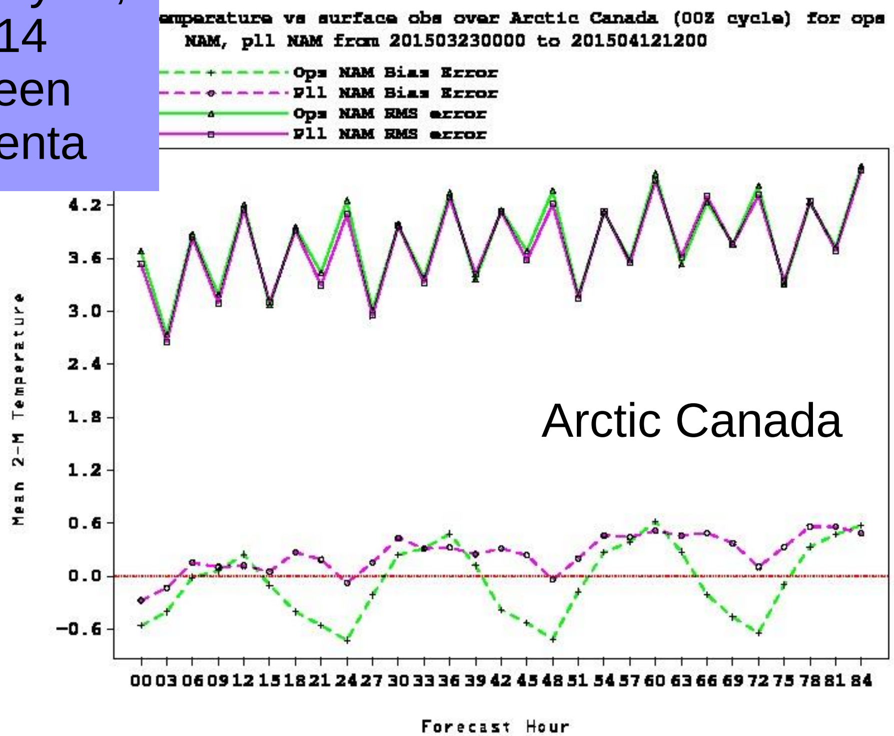
- Limit top-layer soil moisture to 80% of SMCREF (soil moisture threshold below which transpiration begins to stress)
- Threshold snow depth (water equivalent in meters) that implies 100% snow coverage is increased by 4x
- Targeted to reduce cool/moist bias

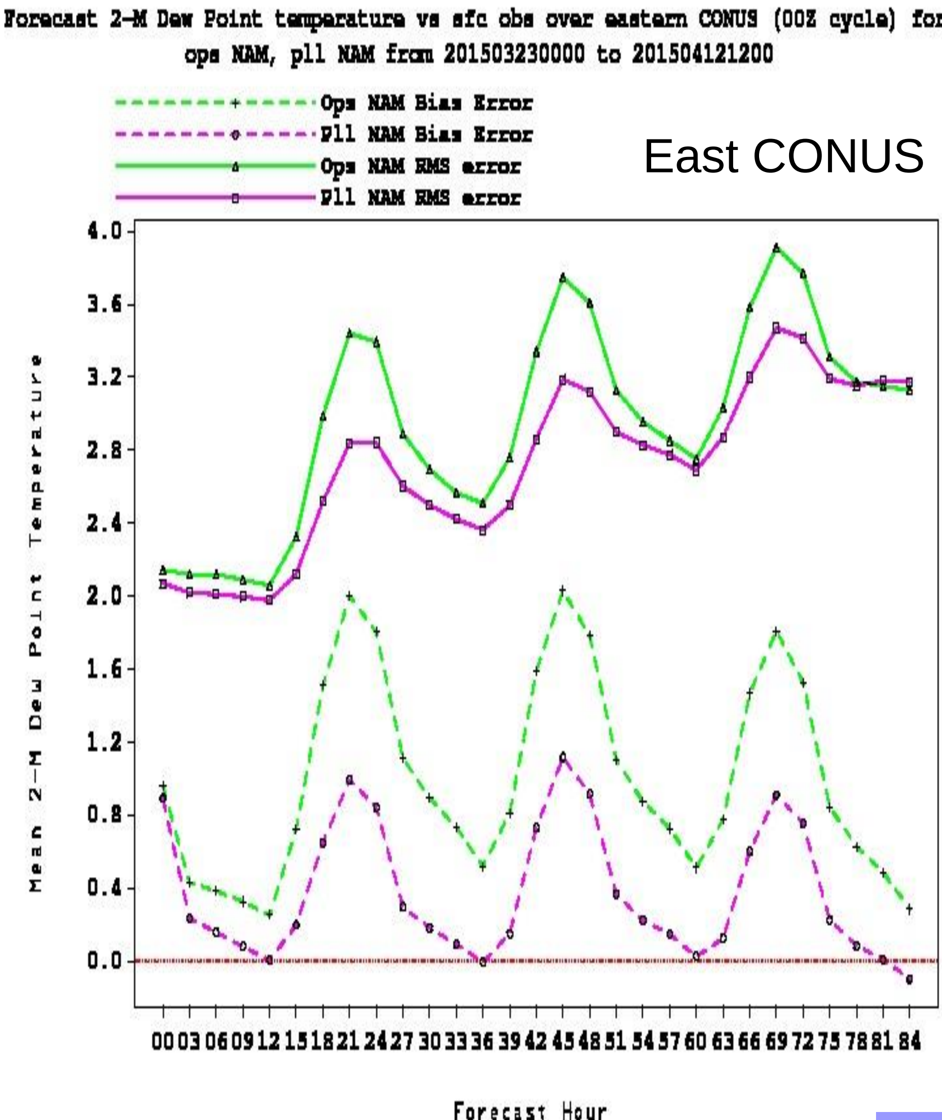


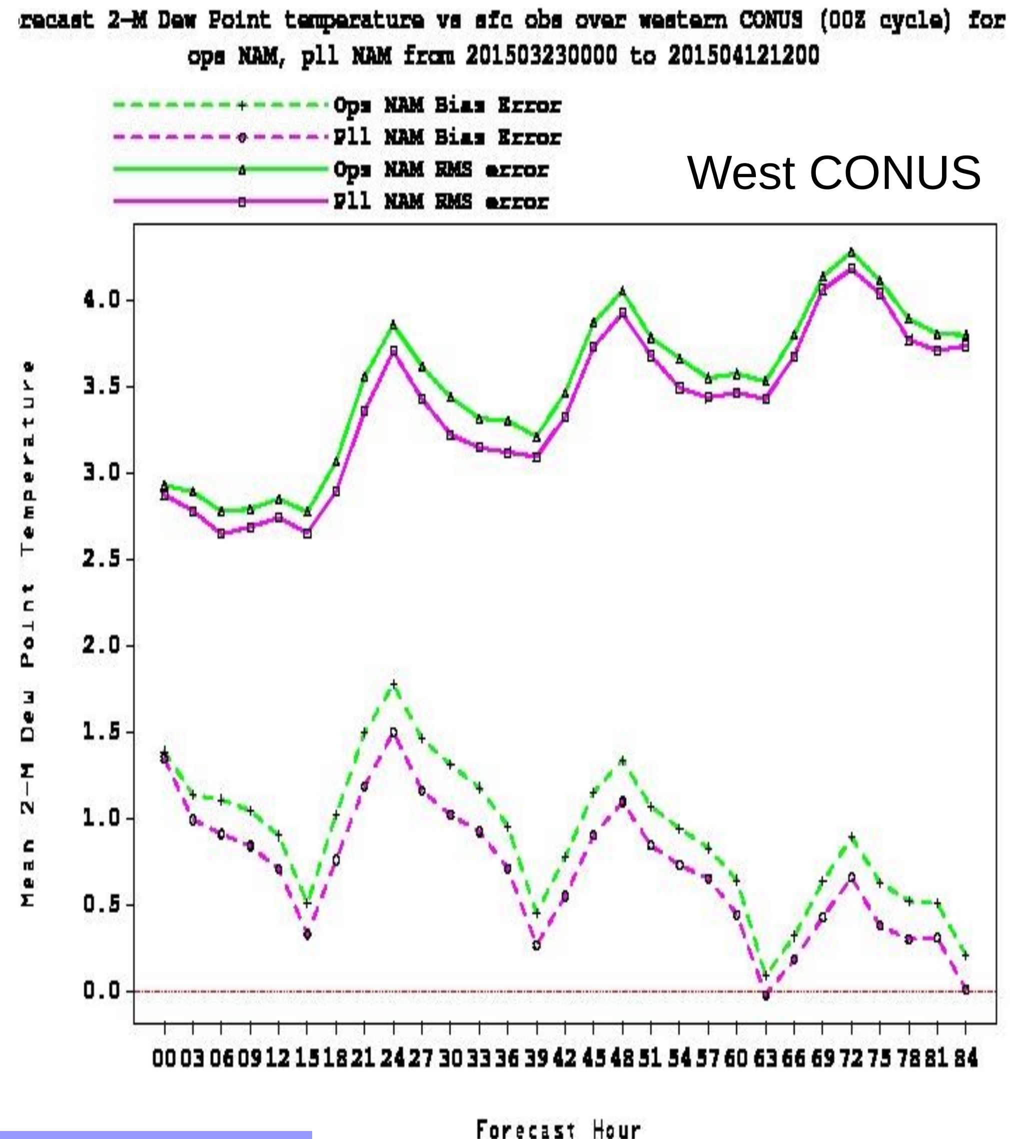


2-m T RMS (solid)/ Bias (dashed) Error, 00Z cycle; 3/23-4/14
Ops-Green
Pll=Magenta







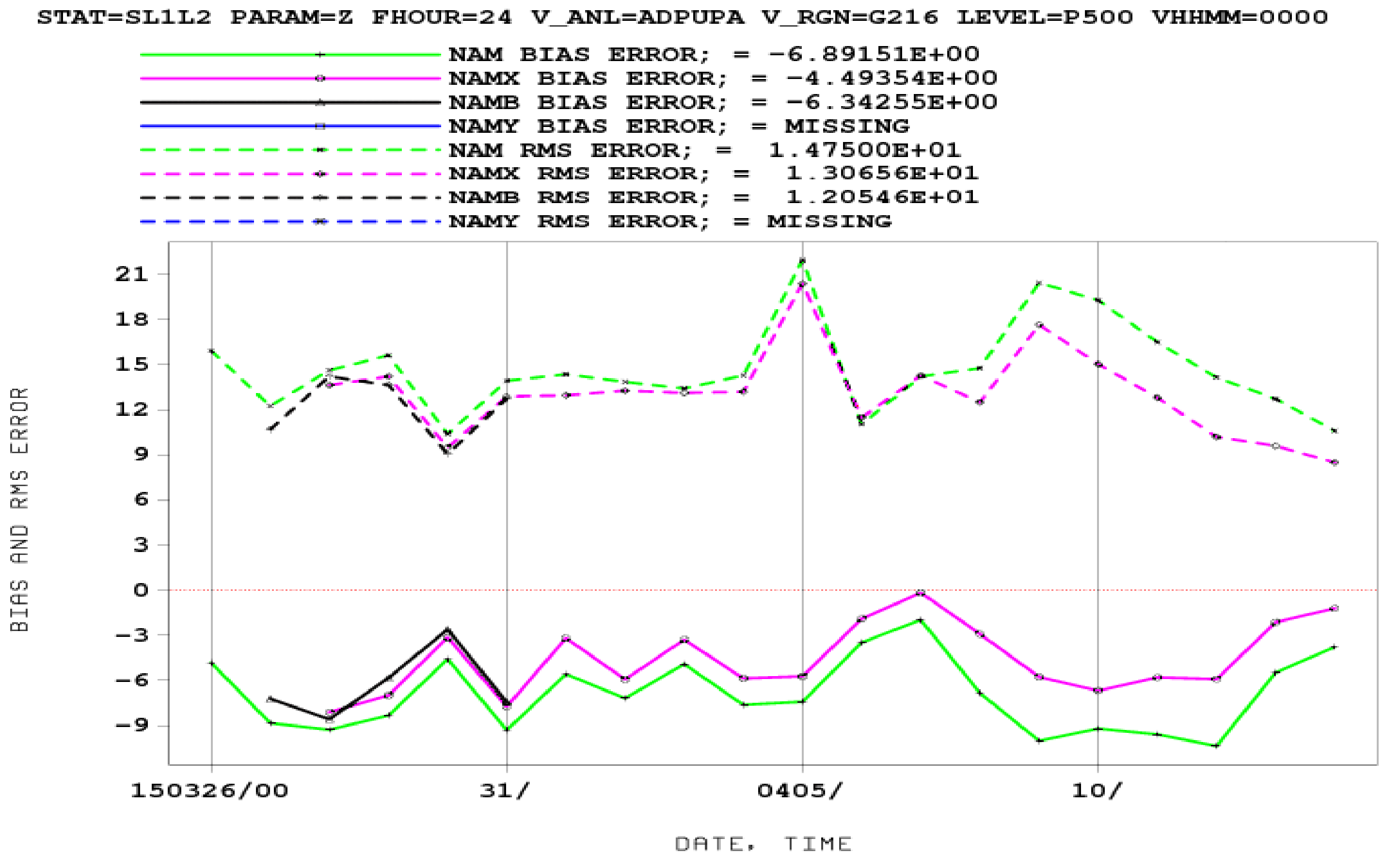


2-m Td RMS (solid)/ Bias (dashed) Error, 00Z cycle; 3/23-4/14
Ops-Green
Pll=Magenta

Physics Changes : PBL

- Enhanced mixing at top of PBL under moist conditions where (1) the theta-e decreases with height and (2) the air is close to saturation.
- Targeted to reduce maritime shallow cloudiness; not much impact seen thus far, but changes are tunable and other possible changes are under development
- But.........

Time Series of Alaska/Western Canada 24-h 500 mb RMS (dashed)/bias (solid) height errors; 00z cycle
Ops = Green, Parallel = Magenta



Improvement started w/12z 4/7 cycle; also seen in lower tropospheric T, little difference above 500 mb. Improvement in RMS error coincides with PBL change; changes to ratio of ensemble to static background in GSI and LSM changes might also be involved

Other Model Changes

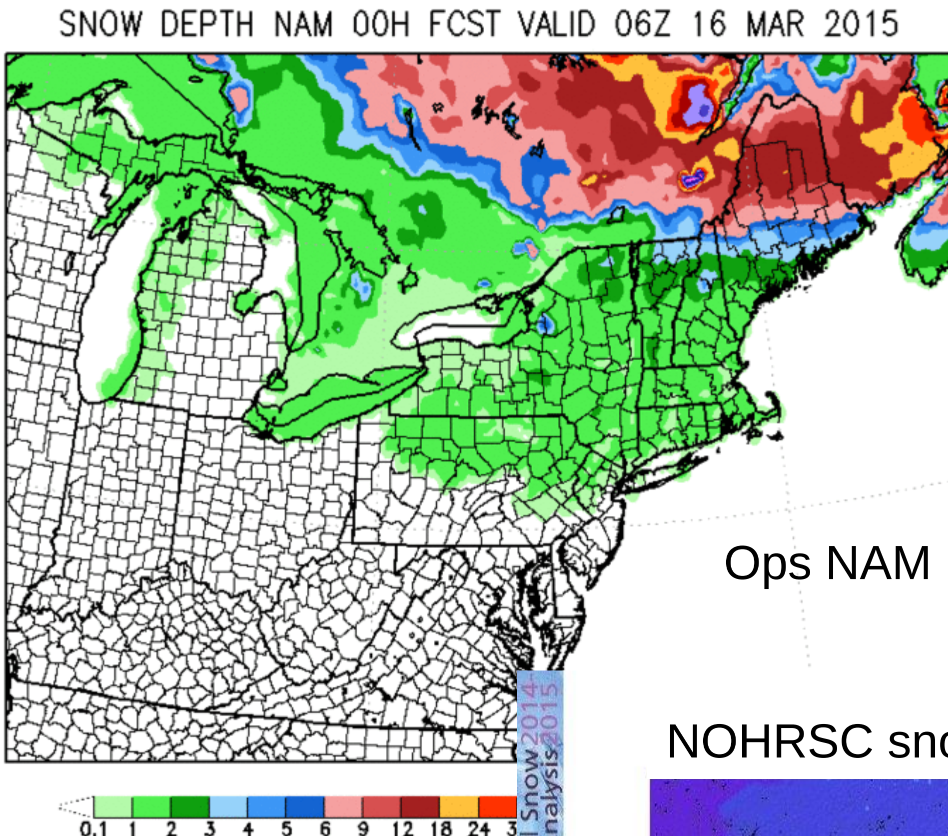
- Model time step change; done to fix CFL problems in 3 km CONUS nest
  - 12 km parent : 26 2/3 sec --> 25 sec
  - 3 km nests : 6 2/3 sec --> 6 1/4 sec
  - 1.5 km nest : 3 1/3 sec --> 3 1/8 sec
- Frequency of physics calls : better consistency
  - Convection/Microphysics/PBL: Call every 4 time steps instead of every 6
    - 12 km parent : 160 s --> 100 s
    - CONUS nest : 44 4/9 s --> 25 s
  - Radiation
    - Call every 20 min instead of 1 hour in 12 km parent, already 20 min for nests except.......
    - Call every 10 min instead of every 5 min in fire weather nest (was unintentionally set to 5 min back in 2014)

Snow in current OPS NAM

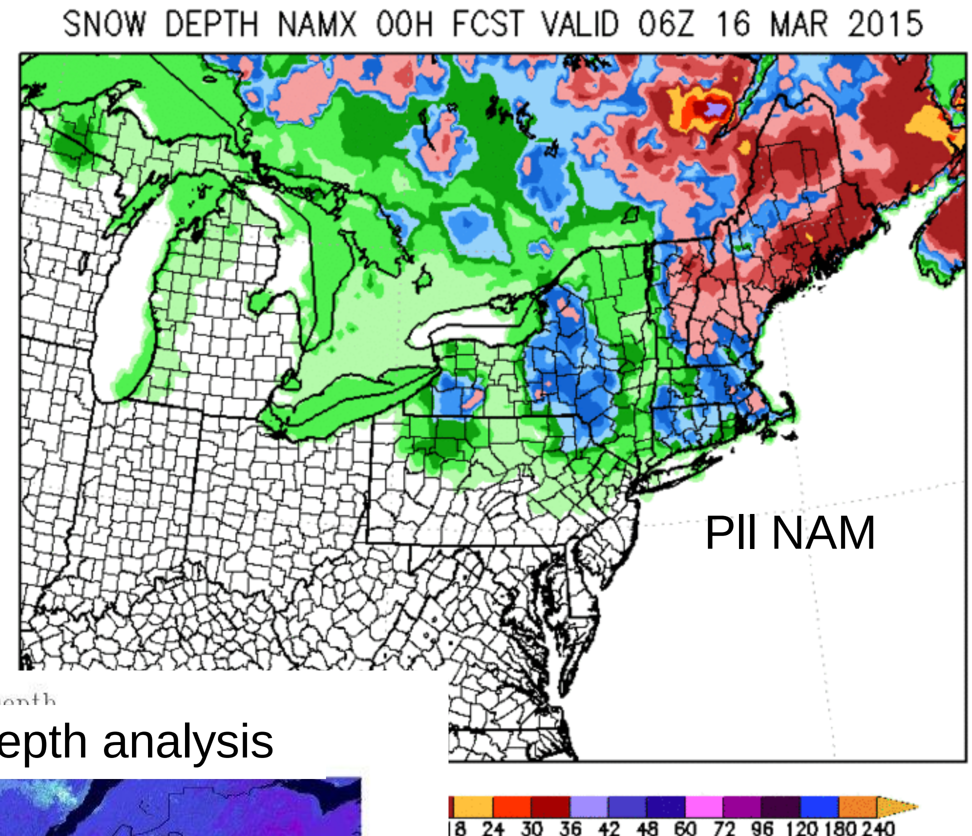
- Dropped AFWA snow depth use in NDAS in last implementation due to QC issues during 2013-2014 winter
- Snow depth is cycled in ops NDAS; snow cover updated at 06z from IMS snow cover product; if IMS indicates snow at a point in the NDAS that has no snow, a minimum depth of 5 cm is set
- The NAM melted the deep snow cover in New England too early over the last month
- The new IMS snow depth product is not ready for ops use; AFWA snow depth product performed much better this winter
- Therefore, test use of AFWA snow depth in parallel NAM w/the envelope adjustment method used in the GFS

New Snow Depth Treatment

- Use “envelope” approach to blend the external analysis with the model first guess.
  - Added several years ago for the global reanalysis project.
- This method compares model first guess depth against the external analysis.
  - If first guess within a specified range or “envelope”, then snow is cycled at that grid point.
  - If first guess outside the “envelope”, the first guess is adjusted toward the lower/upper bound of “envelope”.
- Gives ‘weight’ to the model first guess

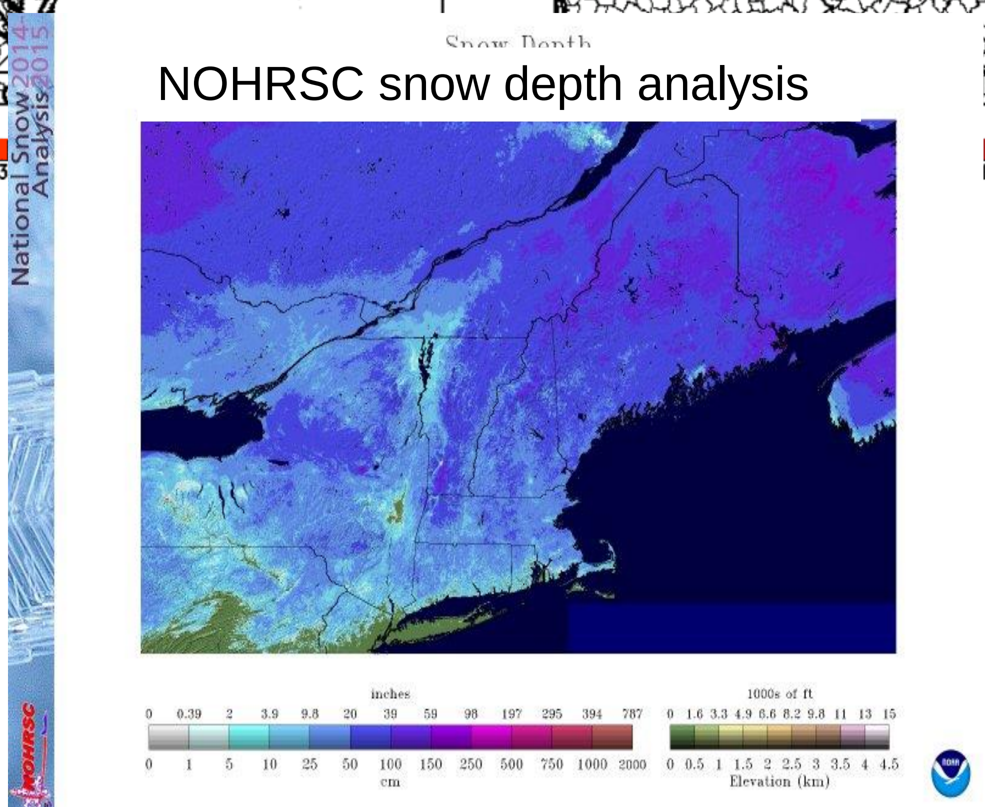


Ops NAM



Pll NAM

NOHRSC snow depth analysis



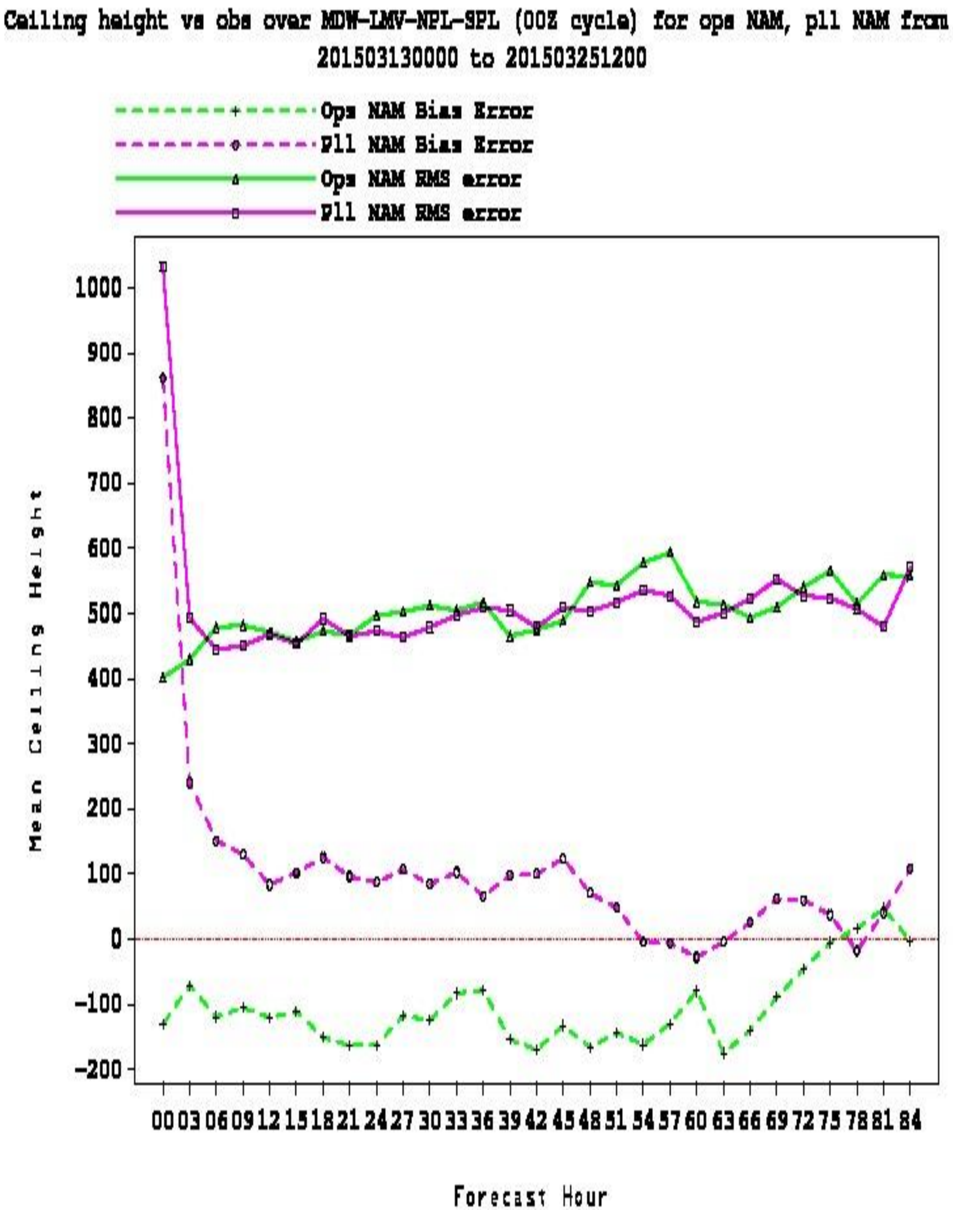
Post-processing changes

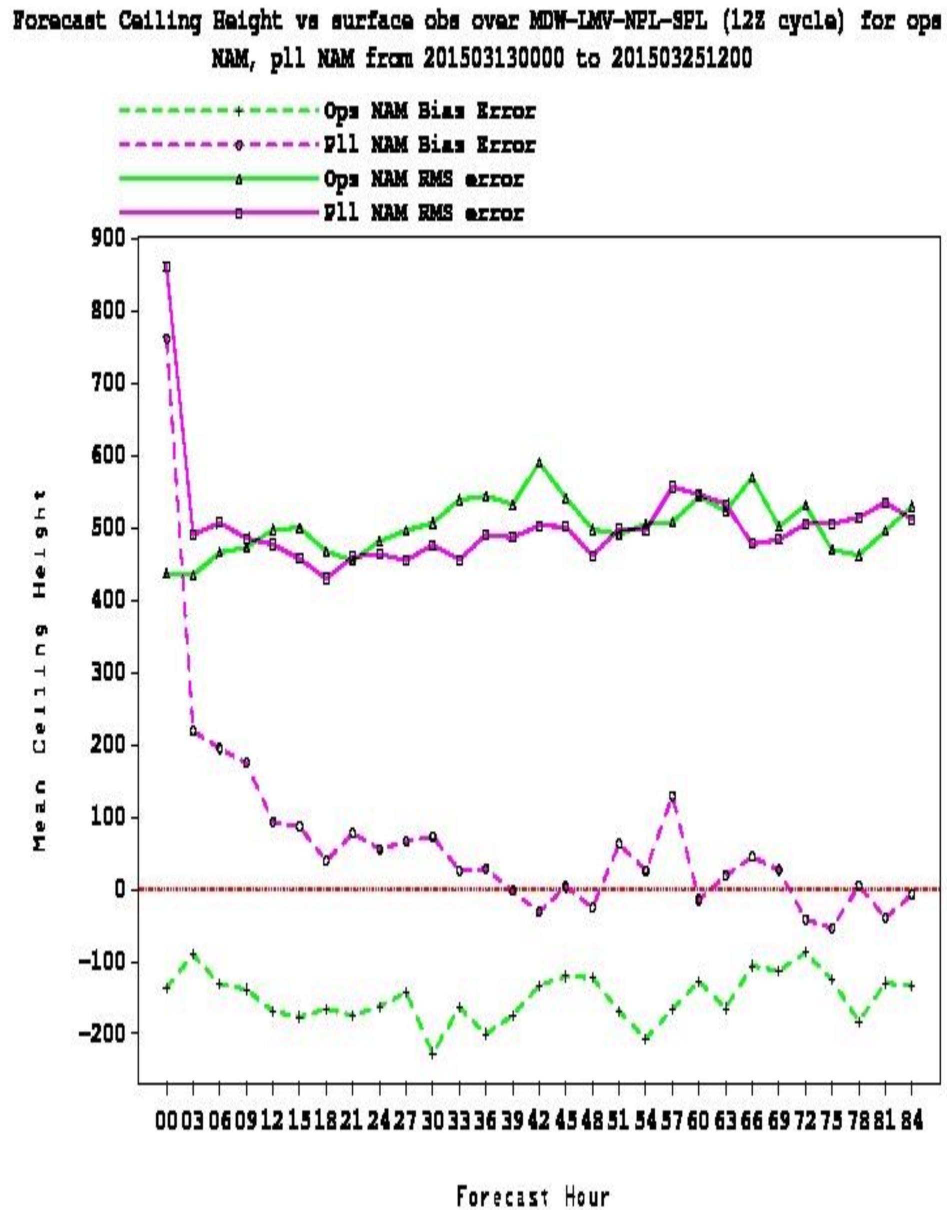
- All NAM output will be GRIB2 direct from the post-processing
- To address AWC's feedback on NAM AVN products, test a new ceiling height computation based on Stoelinga & Warner (1999, JAM) computing ceiling heights as a vertical visibility
- Investigate use of GSD visibility/ceiling height/cloud fraction algorithms
- Fixes to calculation of updraft helicity

Post-processing changes

- CONUS nest output grid will change to the same grid as that from the HRRR
- Based on discussions at the last NPSR, a new grid with a subset of fields from the CONUS nest will be created, intended to be a common set of fields from NCEP Convective-allowing models (NAM nest, HRRR, HiResW)
- Alaska nest will be output on the 3 km Alaska DNG grid

Early look at ceiling height verification : "Interior CONUS" region: Midwest / Great Plains / Lower Mississippi Valley
Solid=RMS error, Dashed=bias, Green=Ops, Magenta=Pll





Under Development

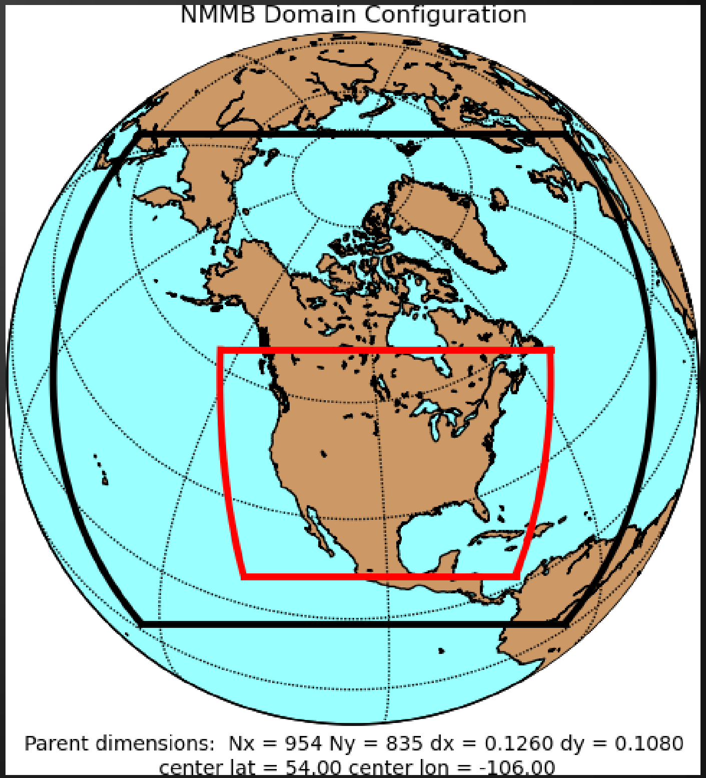
- Analysis/Assimilation
  - New ob types (SEVIRI, NOAA 17-18 SSMIS, Metop-B, NPP)
  - 4-d version of hybrid analysis (tentative)
  - Tropical cyclone relocation
- Model
  - Physics changes to address locally heavy QPF, additional changes to improve PBL cloudiness

Hourly-Updated NAM Forecast System

How does this fit within NCEP production suite?

- NAM – North American Mesoscale forecast system
  - ○ Runs 4x daily at 00, 06, 12, 18Z
  - ○ Short-range mesoscale NWP system for the U.S. which provides guidance to day 3.5

- NAM*RR*: NAM Rapid Refresh
  - *Hourly updates*
  - **<u>Important step toward Standard Resolution and Hi-Res Rapid Refresh Ensemble Forecast systems (SREF-RR and HREF-RR)</u>**
  - **<u>NAMRR + RAP/HRRR Foundation</u>**
  - Consistent with 2014 Annual Report of the UCAR Community Advisory Committee for NCEP

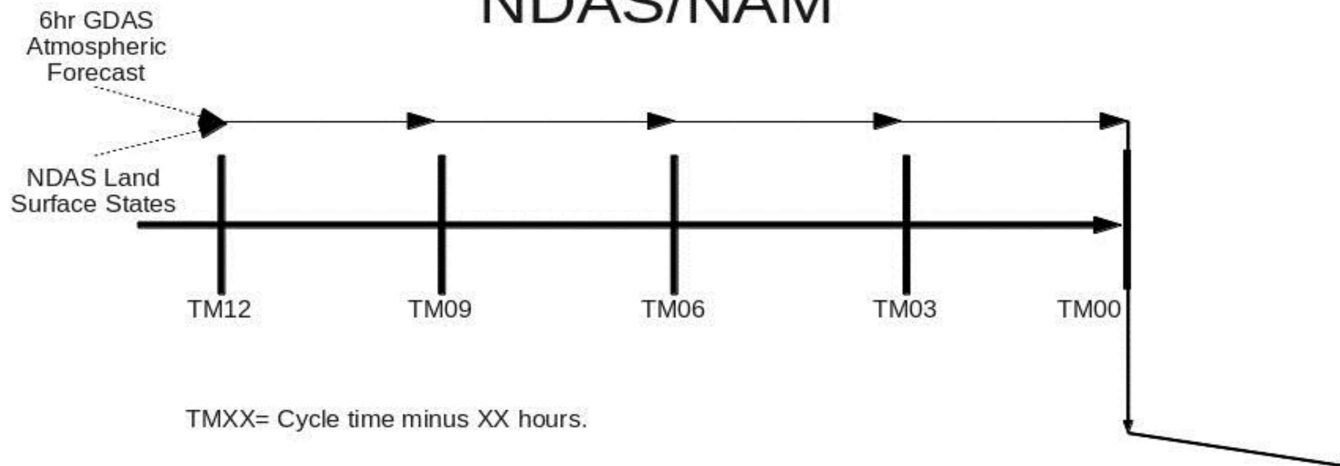


- Development of *hourly* NAM cycling capabilities originally a part of DOE-funded wind energy projects
  - WFIP/POWER
  - Cycling 12 km NAM *<u>and</u>* 3 km CONUS nest (cycled 3 km Alaska nest is planned)

NAM*RR* Overview

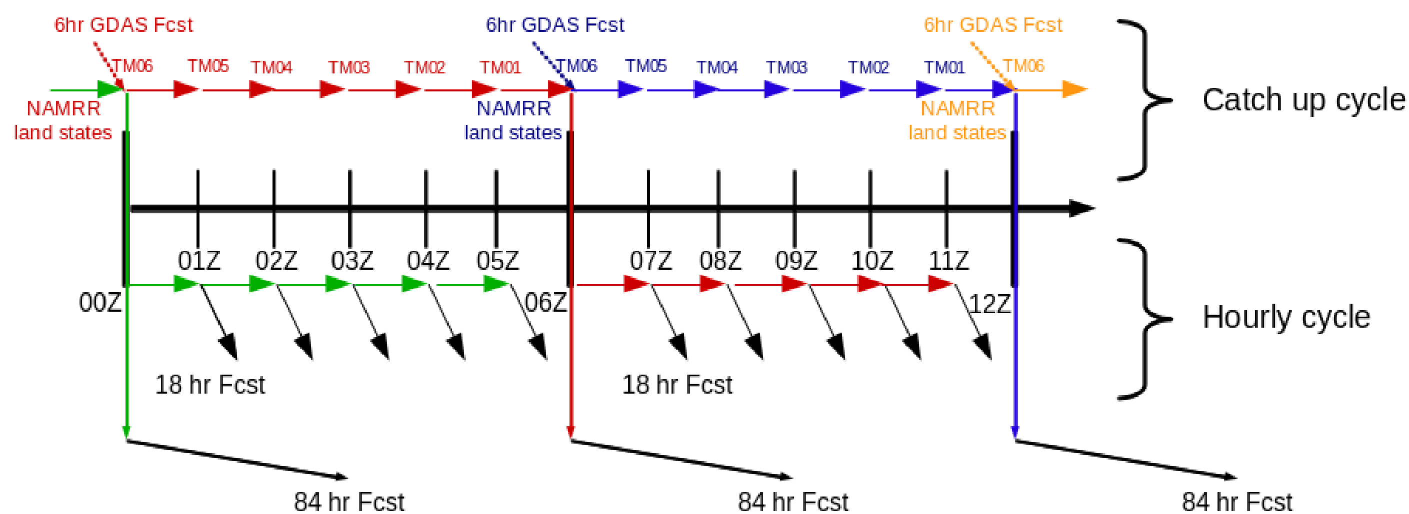
Current : NAM Data Assimilation System (NDAS) configuration for a single, arbitrary cycle, w/3-h anl/fcst

NDAS/NAM



Example: NAMRR configuration for 12 1-h cycles

NAM*RR*

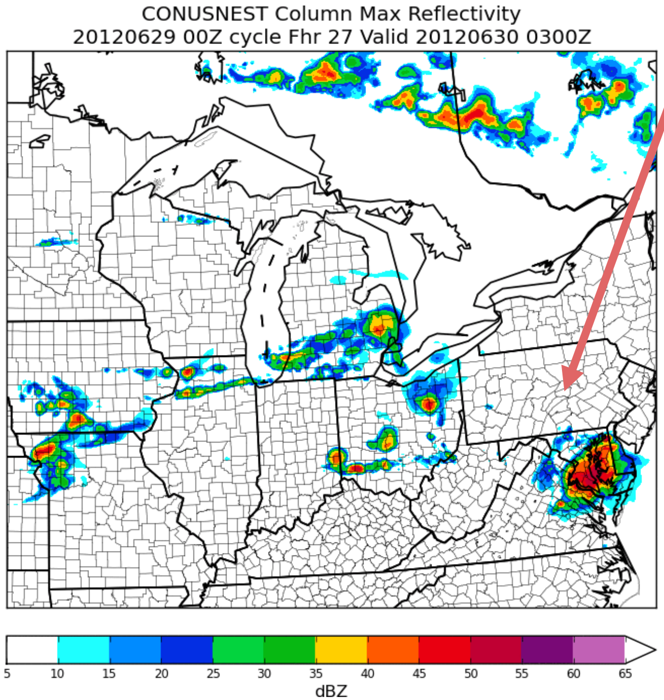


- **Hourly cycled assimilation of 12 km parent; 3 km CONUS/Alaska nest**
- **18-24 h forecast of 12 km parent + 3 km CONUS + 3 km Alaska every hour**
- **Every 6-h, full 84-h NAM forecast with parent + all nests**

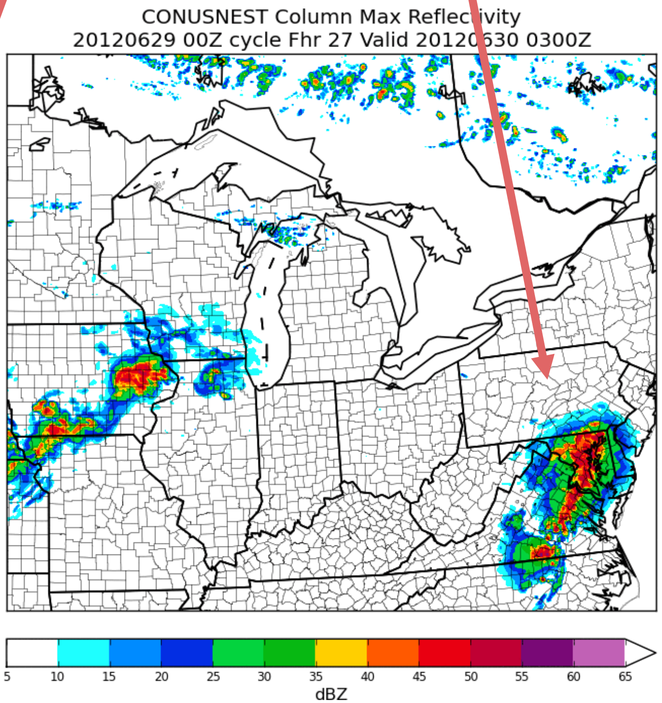
- TMXX= Cycle time minus XX hours.
- Colors denote a continuous thread of cycling which begins by using the land states from the previous catchup cycle and a 6 hour forecast from the GDAS as the first guess for the atmospheric state at TM06.

June 29-30, 2012 Derecho - 27 Hr Forecast
NAMRR Test with *3 km CONUSnest*

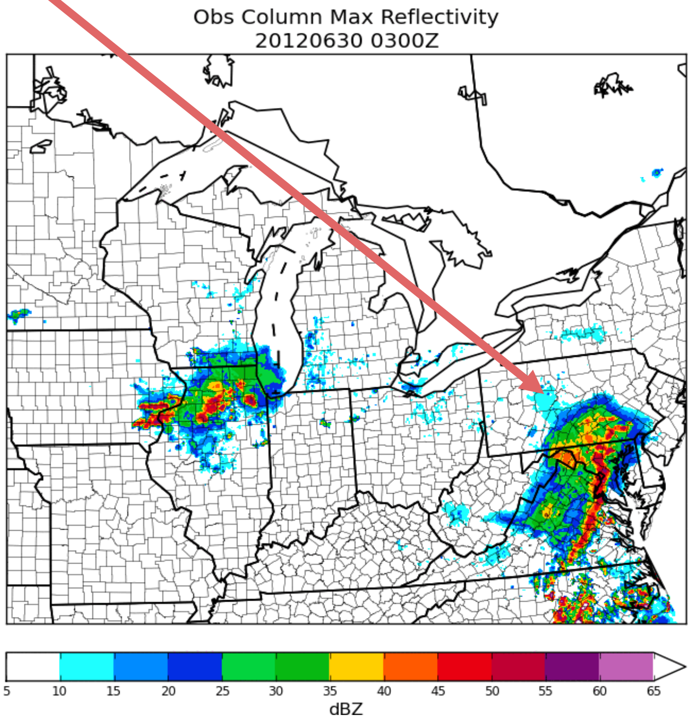
Significant improvement at longer lead times
with *3 km* NAMRR relative to Ops (at the time)



4 km Ops NAM CONUSnest
Fhr=27

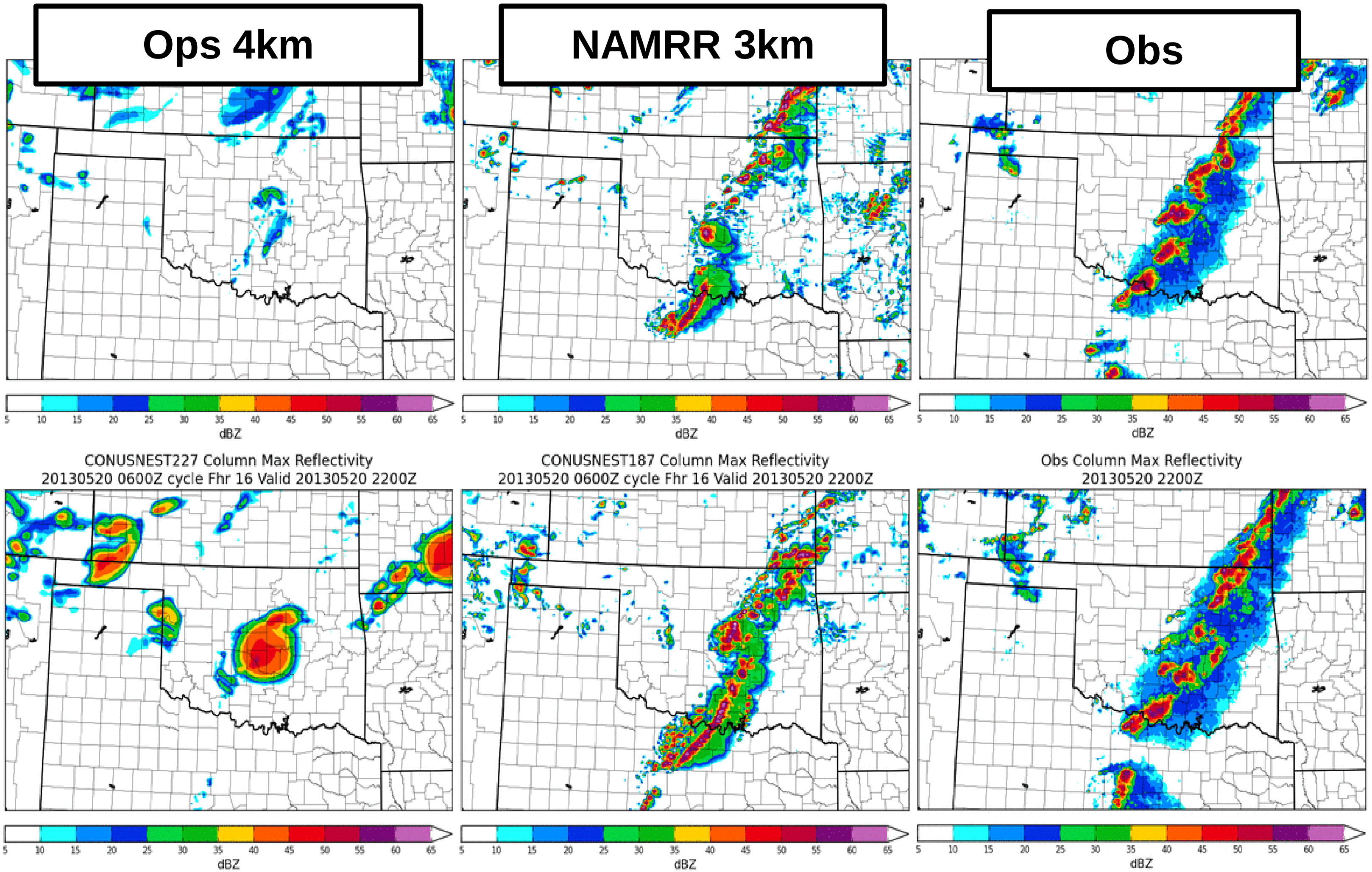


3 km NAMRR CONUSnest
Fhr=27



Observations

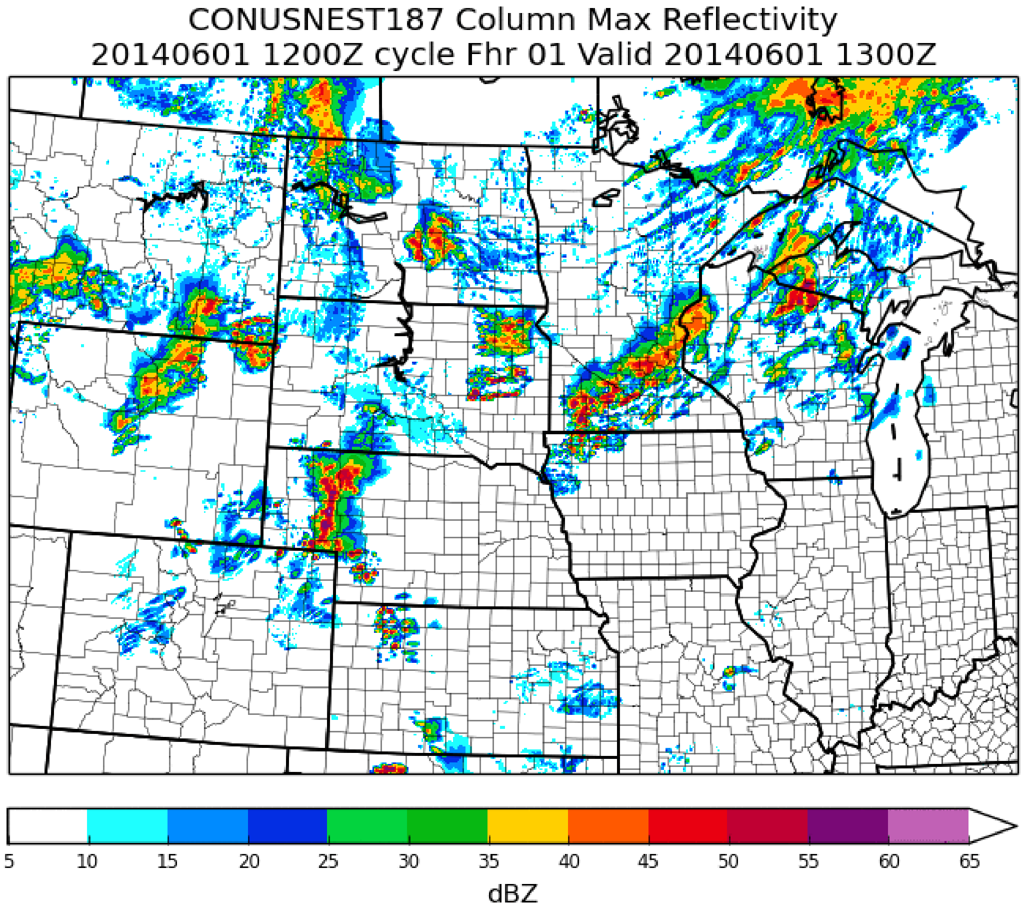
May 20th, 2013 OK Severe Weather Event

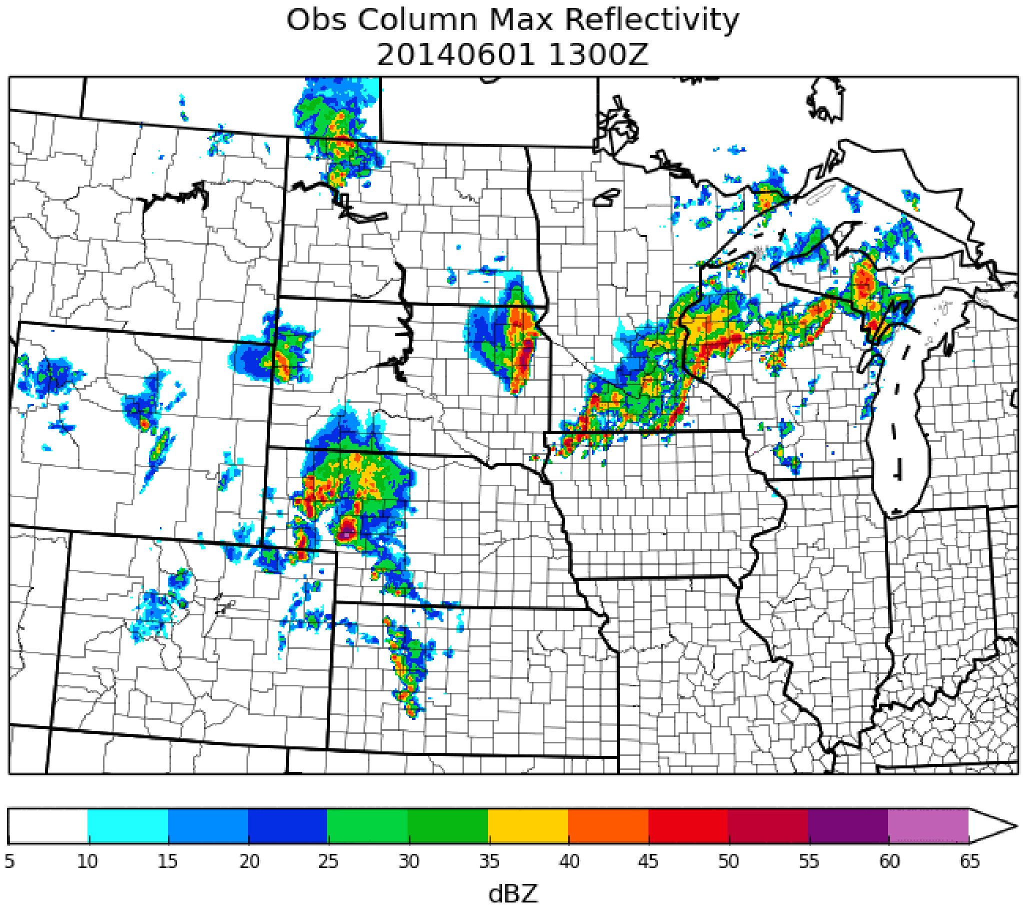


Fhr = 03
Valid 21Z

Fhr = 16
Valid 22Z

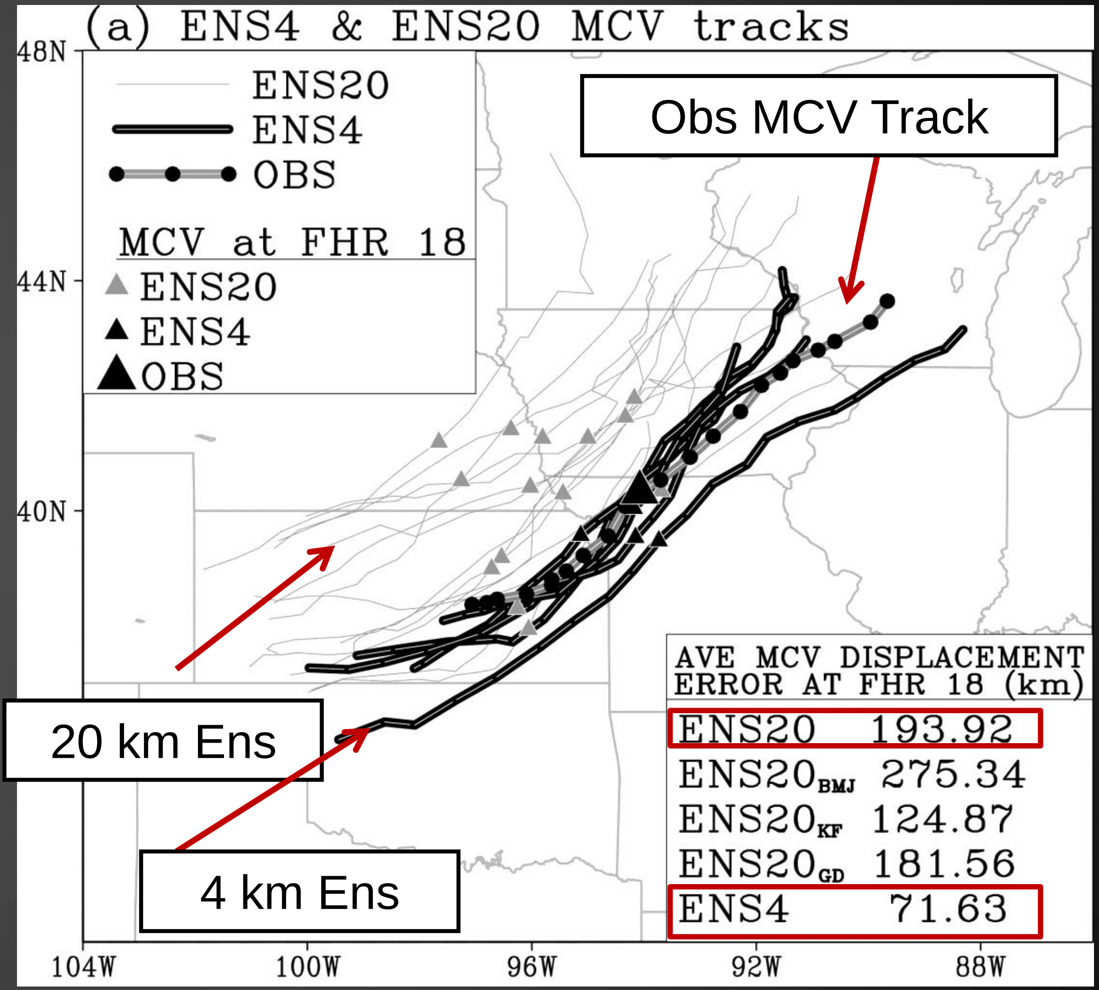
1 June 2014: Large QLCS over Great Plains





Motivation – Why the desire to move to convection-allowing ensembles?

- Convection-allowing benefits
  - No parameterized convection
  - Realistic mesoscale details when dx <= ~4 km
  - Though recent research suggests dx <= 3 km may be more appropriate (Potvin and Flora 2015, *MWR*)
  - Need ~ 100m to be resolving
- Recent works have demonstrated benefits of convection allowing ensembles (e.g. Jirak et al., 2012 SLS Conf; Clark et al. 2010, *WaF*)
- But more is needed to confront issues related to configuration
  - Esp. from an operational perspective of limited resources



20km and 40km ensemble forecast MCV tracks. From Clark et al. 2010, *WaF.*

“Grand Scheme”: Where is this all going?

SREF-RR + SREF

9-12 km Continental

SREF-RR [**Standard Resolution Ensemble Forecast – Rapid Refresh**]

- Hourly
- 18-27 hr forecast range
- Subsumes RAP + NAMRR

SREF [**Standard Resolution Ensemble Forecast**

- 6 hourly
- 84-96 hr forecast range with extending of SREF-RR members
- Subsumes NAM and current SREF

HREF-RR + HREF

3 km CONUS, AK, HI, PR

HREF-RR [**High Resolution Ensemble Forecast – Rapid Refresh**]

- Hourly
- 15-24 hr forecast range
- Subsumes HRRR + NAMRRnests

HREF [**High Resolution Ensemble Forecast]**

- 6 hourly
- 48-60 hr forecast range by extending of HREF-RR members
- Subsumes HiResWin + NAMnests

“Grand Scheme”: Where is this all going?

SREF-RR + SREF

12 km Continental

SREF-RR [**Short Range Ensemble Forecast system – Rapid Refresh**]

- Hourly
- 18-24 hr forecast range
- Subsumes RAP + NAMRR

SREF [**Short Range Ensemble Forecast system**]

- 6 hourly
- 84-96 hr forecast range with extensions of SREF-RR members 00Z, 06Z, 12Z, and 18Z
- Subsumes NAM

HREF-RR + HREF

3 km CONUS, AK, HI, PR

HREF-RR [**High Resolution Ensemble Forecast m – Rapid Refresh**]

- Hourly
- 15-18 hr forecast range
- Subsumes HRRR + NAMRRnests

HREF [**High Resolution Ensemble Forecast]**

- 6 hourly
- 48-60 hr forecast range by extending of HREF-RR members
- Subsumes HiResWin + NAMnests

“Grand Scheme”: Where is this all going?

SREF-RR + SREF

12 … Continental

SRE… [Short Range Ens… orecast syste… d Refresh]

This is possible - maybe even probable, at some point in future

SREF [Short R… le Forecast system]

- 6 h…
- … hr foreca… with … nsions of SR… members … Z, 06Z, 12Z, and …
- Subsumes NAM

HREF-RR + HREF

3 km CONUS, AK, HI, PR

HREF-RR [**High Resolution Ensemble Forecast m – Rapid Refresh**]

- Hourly
- 15-18 hr forecast range
- Subsumes HRRR + NAMRRnests

HREF [**High Resolution Ensemble Forecast**]

- 6 hourly
- 48-60 hr forecast range by extending of HREF-RR members
- Subsumes HiResWin + NAMnests

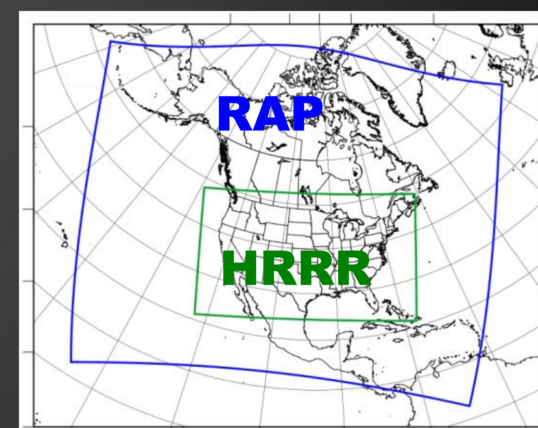
Final Thoughts

- NAMRR establishment in production will be a significant step toward the realization of rapid update ensembles
  - NAMRR/RAP+HRRR Foundation → new SREF-RR and HREF-RR
    - Multi-model, convection-allowing (HREF-RR), rapid update ensemble
  - May take full advantage of multi-model approach since each system is already supported by a center (RAP/HRRR – GSD and NAMRR – NCEP/EMC)
    - Concept supported by very recent work that showed combining convection-allowing ensembles from multiple operational NWP (European) centers was beneficial (J. Beck 2015, personal comm. – manuscript submitted)
    - Helps mitigates the legitimate concern regarding difficulty of maintaining a multi-model ensemble
- As development matures – will ***need*** input/engagement from the community
- Late FY15 or early FY16 implementation

SREF/HREF (RR) **=**

N Member Ensemble

+



N Member Ensemble

Thank you! Questions? Discussion?

Backup NAMRR slides

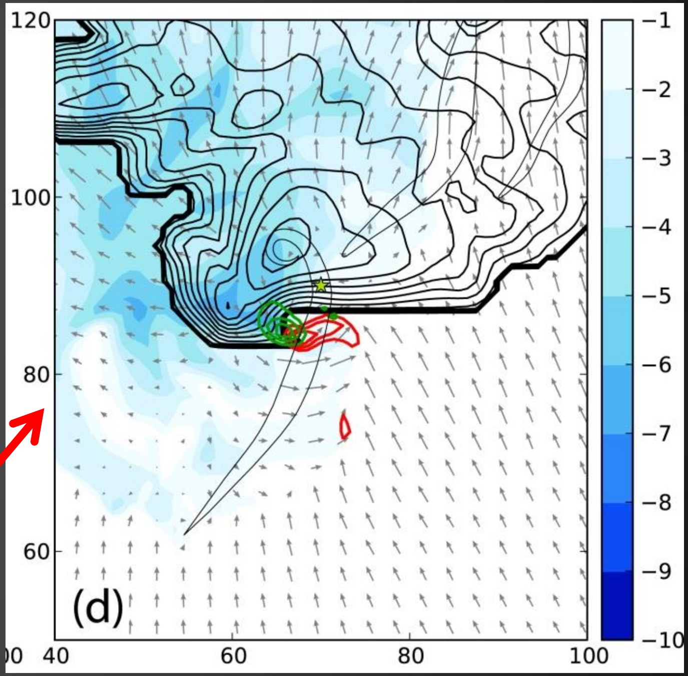
Convection-allowing ensemble design

A very brief, non-exhaustive, review of some terminology (I’m no expert!)

- **Multi-model**
  - Multiple dynamic cores to account for model error
  - e.g., WRF-ARW + NMMB
- **Multi-physics**
  - Use of a variety of physics schemes in an ensemble (model error)
  - e.g., use different combinations of microphysics or PBL schemes
- **Perturbed *LBCs***
  - For limited area models, perturb the lateral boundary conditions
  - Typically comes from a global ensemble forecast system (e.g. the GEFS)
- **Perturbed *ICs***
  - Account for uncertainties in the initial conditions
  - May be combined with DA (EnKF) or be somewhat separate.
    - Perturbations may often come from a global ensemble forecast system
- **Stochastic physics (SPPT)**
  - Perturbations to tendencies from model physical processes
    - Applied during the model integration, can have space/time correlation
- **Stochastic energy backscatter (SKEB)**
  - Intended to account for “missing” physical processes in turbulent energy cascade via introduction of correlated perturbations to streamfunction and potential temperature
- **Or some/any combination of the above!**

Convection-allowing ensemble design challenges

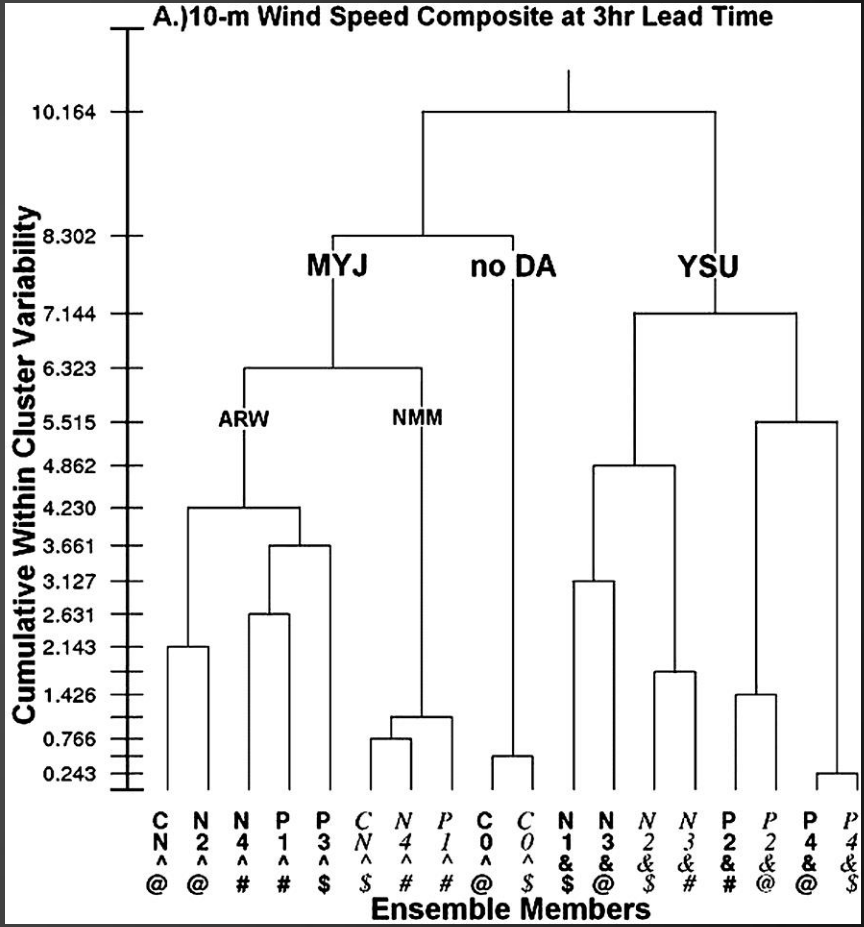
- (under)Dispersion
  - IC perturbations alone are insufficient, making the ensemble underdispersive (e.g. Schwartz et al. 2014, *WaF*).
  - "For short-range predictions of convective weather, on the other hand, accounting for model errors and uncertainties in addition to those associated with the initial conditions becomes important as well (e.g., Stensrud et al. 2000; Eckel and Mass 2005)." – Schumacher et al. 2014 (*MWR*)
- Representation of model error
  - A variety of methods (see previous slide)
- Convection-allowing ensembles involving a DA cycle (e.g. EnKF) have generally focused on Warn-on-Forecast like settings
  - 0-3 hr forecast, assimilation of radar data every 5 minutes for 60 minutes, often focus on a single storm (or handful of storms)
- *Very little* research with stochastic physics and/or SKEB with convection-allowing ensembles to date
  - Romine et al. 2014 and Bouttier et al. 2012 (*MWR*) are the only ones I am aware of (certainly could be others I've missed)



EnKF initialized forecast of Greensburg, KS supercell from 7 May, 2004. Perturbation potential temperature at 75 m AGL is shaded. From Dawson et al. 2012, *MWR*.

Convection-allowing ensemble design challenges

- Some knowns
  - Multi-model approaches can be effective
    - Clustering by model may be an issue but clustering by physics in a multi-physics approach may be an issue too (Johnson et al. 2011, *MWR*)
  - IC perturbations and multi-physics approaches are effective
    - Much research has been done by CAPS with their Storm Scale Ensemble Forecast system (SSEF)
      - Multi-physics, Multi-model (some years), IC and LBC perturbations
    - e.g. Duda et al. 2014, *MWR* → microphysics
  - SKEB, SPPT, and perturbed LBCs improves ensemble forecast reliability and some ensemble metrics (Romine et al. 2014, *MWR*)
    - But can degrade individual ensemble member forecasts
- And what about ensemble size?



Example of ensemble clustering from the 2009 CAPS SSEF. From Johnson et al. 2011, *MWR*.